

DAMAGE PROGRESSION IN COMPOSITE STRUCTURES

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Summary: A computational simulation tool is used to evaluate the various stages of damage progression in composite materials during Iosipescu shear testing. Unidirectional composite specimens with either the major or minor material axis in the load direction are considered. Damage progression characteristics are described for each specimen using two types of boundary conditions. A procedure is outlined regarding the use of computational simulation in composites testing.

Iosipescu shear testing using the V-notched beam specimen is a convenient method to measure both shear strength and shear stiffness simultaneously. The method was originally proposed by Nicolae Iosipescu for metals [1]. ASTM standard D5379/D5379M “Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method,” describes the test method for the evaluation of shear properties of fiber composite materials. The D5379/D5379M standard is presently limited to short random fiber composites and unidirectional, cross-ply or woven laminates with either the major or minor principal laminate direction oriented along the loading axis. The main reason for the current limitation of the D5379/D5379M standard to unidirectional and cross-ply laminates is that when multidirectional quasiisotropic and angle-ply laminates are tested, the failure mode does not emerge as a clearly defined shear failure plane at the notch.

The evaluation of composite test response can be made more productive and informative via computational simulation of progressive damage and fracture. Computational simulation performs a complete evaluation of laminated composite fracture via assessment of ply and subply level damage/fracture processes. Computational simulation may be used prior to the testing of a fiber composite specimen for

evaluation of damage initiation and fracture propagation mechanisms under the applied load, hygrothermal conditions, and fabrication process parameters. Progressive damage mechanisms, damage locations/modes, and sensitive parameters affecting specimen failure can be identified prior to testing, significantly enhancing the accuracy and productivity of an experimental program.

In general composite structures are much more damage tolerant compared to homogeneous structures. A local material failure in a composite structural component will not usually mean immediate structural fracture. It is important to have a capability to quantify the level of structural safety after damage initiation and damage growth take place. The relationship between certain damage characteristics and remaining reliable life need be established for in-service structural health monitoring of structural components. Thermal, hygral, and environmental effects on structural response need be quantified in order to define a framework for the development of reliable test methods.

The present computational simulation approach by-passes traditional fracture mechanics to provide an alternative evaluation method, conveying to the design engineer a detailed description of damage initiation, growth, accumulation, and propagation that would take place in the process of ultimate fracture of a fiber composite specimen. Results show in detail the damage progression sequence and structural fracture resistance during different degradation stages. This paper demonstrates that computational simulation, with the use of established material modeling and finite element modules, adequately tracks the damage growth and subsequent propagation to fracture for fiber composite specimens.

For the purpose of the present study, the following terminology is used to describe the various stages of degradation in the composite structure: (1) *damage initiation* refers to the start of damage induced by loading that the composite structure is designed to care; (2) *damage growth* is the progression of damage from the location of damage initiation to other regions; (3) *damage accumulation* is the increase in the amount of damage in the damaged regions with additional damage modes becoming active; (4) *damage propagation* is the rapid progression of damage to other regions of the specimen; (5) *structural fracture* is the ultimate disintegration of the specimen.